Faculty of Resource Science and Technology

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Elizabeth Sinda Anak Tawai

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ELIZABETH SINDA ANAK TAWAI

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Elizabeth Sinda anak Tawai

Programme of Resource Aquatic and Management
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak

ABSTRACT

This study was carried out to determine the effect of turbid water on the growth and mortality of the fries of sayan *Leptobarbus hosii* and tengadak *Puntius schwanenfeldii*. Recirculating water system was used in this study. The amount of suspended solids used was 300 mg/l. A clear water culture system was used as a control. There were eight replicate tanks for treatment and control and each tank was filled with a 34 L of water. Ten fries were placed in each of the tank. Measurements for total length, standard length, and body weight was taken once every two weeks. Mortality was recorded every day. In turbid water culture system, tengadak has a lower total length (8.5 %), standard length (12.8 %), and body weight (25.6 %) than sayan. Mortality for sayan (30 %) was higher than tengadak (21.25 %). Feed conversion ratio (FCR) is similar for sayan and tengadak in both water systems (0.30). This study shows that the effect of suspended solid differs among different species even though they are of the same life stage.

Key words: Recirculating water system, suspended solid, reverine fish, growth, mortality.

ABSTRAK

Kajian ini dijalankan untuk mengkaji kesan air keruh keatas tumbesaran dan kemortalan anak benih sayan Leptobarbus hosii dan tengadak Puntius schwanenfeldii. Sistem guna semula air digunakan dalam kajian ini. Jumlah pepejal terampai yang diginakan ialah 300 mg/l. Sistem kultur air jernih digunakan sebagai kawalan. Terdapat lapan tangki replikat untuk tnagki kajian dan kawalan dan setiapnya diisi dengan 34 L air. Sepuluh ekor anak ikan diletakkan kedalam setiap tangki. Ukuran bagi panjang total, panjang piawai, and berat badan direkodkan sekali dalam dua minggu. Kemortalan direkodkan pada setiap hari. Di dalam air keruh tengadak mempunyai panjang total (8.5 %), panjang piawai (12.8 %), dan berat badan (25.6 %) yang lebih rendah berbanding sayan. Kadar kemortalan sayan (30 %) adalah lebih tinggi berbanding tengadak (21.25 %). FCR bagi sayan dan tengadak adalah hampir sama untuk kedua-dua sistem kultur (0.30). Kajian ini menunjukkan kesan pepejal terampai adalah berbeza untuk spesis yang berbeza walaupun pada peringkat hidup yang sama.

Kata kunci: Sistem guna semula, pepejal terampai, ikan sungai, tumbesaran, kemortalan.

INTRODUCTION

Water quality is the summation of all physical, chemical, biological and aesthetic characteristic of water that influences its beneficial use. Knowledge of water quality principles will helps to maintain or to improve water quality in the cultural system, to minimize the problem of fish stress and fish health, and to reduce environmental impacts of effluents (Boyd and Tucker, 1998). Fish in poor water quality is a prime target for pathogens and parasites (Landau, 1992).

Fish are economically important both commercially and recreationally (Wood and Armitage, 1997). Malaysia is considered as the southern center for primary freshwater fish distribution (Mohsin and Ambak, 1983). Sayan *Leptobarbus hosii* and tengadak *Puntius schwanenfeldii* are some of indigenous fish species that can be found in the rivers of Sarawak (Kumbang & Laing, 1990).

The most abundance fresh water fish species in Malaysia is from the genus *Puntius* and it can be found in almost every water body (Inger and Chin, 1962; Mohsin and Ambak, 1983; Zakaria Ismail, 1990). Tengadak is an indigenous species in upper and mid-zone of Rejang River, Limbang and as well as in Batang Ai rivers (Litis *et al.*, 1997). Sayan is an indigenous species in Baram River (Kottelat *et al.*, 1993). At present, Tengadak is considered as one of the valuable and expensive cyprinid in Malaysia due to its high quality meat and fine taste (Mohsin and Ambak, 1983; Litis *et al.*, 1997). During Ikan Mudik season in Kapit, its market price could reach RM120/kg.

Suspended particle is present in all natural waters of the world (Eisma, 1993). By convention, particulate matter in suspension is defined as the material that is retained on a 0.4μm to 0.5μm pore size filter. Smaller material is considered dissolved but actually it may be colloidal or particulate (Gordon, 1970; Haris, 1977; Eisma *et al.*, 1980).

Suspended particles are made up of sediment particle, organic material, phytoplankton cell and other microorganisms (Stickney, 1979) and soluble colored compounds (Boyd and Tucker, 1998). Turbidity caused by plankton generally is desirable but the undesirable type of turbidity is that resulting from suspended particles of clay (Boyd and Tucker, 1998).

Studies by the Department of Environment, Malaysia (1991) has shown that Sg. Sarawak is heavily polluted by suspended particle. Man activities such as dam construction, land reclamation, deforestation, agriculture increases the suspended particles in rivers (Eisma, 1993). In major rivers in Sarawak, the great amount of total suspended solids is cause by logging activities. Shifting cultivation and other land clearing activities that lead to soil erosions can cause negative impact to rivers (Lal, 1990). Top soil eroded from cultivated land cause siltation (Bolling, 1994).

The primary effect of turbidity was to restrict light and reduce photosynthesis and food production (Buck 1956; Singer and Munnns, 1991). Low light penetration reduced the abundance of food available to fish (Bruton, 1985; Doeg and Koehn, 1994; Gray and Ward, 1982).

Suspended particles that settle down will bury fish eggs. It also fills in marsh grass (Trivedi and Raj, 1992) and gravel (Bolling, 1994), which is their important spawning ground. It will reduced the suitability of spawning habitat and hindering the development of fish eggs, larvae and juveniles, which, these stages appear to be more susceptible to suspended solids than adult fish (Chapman, 1988; Moring, 1982).

Even though turbidity caused by suspended soil particles will seldom have immediate direct effects on fish in ponds, in long run it may harm fish population (Boyd, 1990). The suspended particles limit the vision of fish, making them less wary and easily caught by predator (Swingle, 1945). The mechanical action of suspended solid can lead to clogging and irritation of gills (Stickney, 1979; Bruton, 1985) and generally suffocate fish (Sulaiman, 1994). Particulate matters suspended in water provide a wide surface area for the growth of fungi and bacteria and could increase the potential for disease to occur. Suspended solid reduced fish growth rate, reducing their tolerance to disease or killing them (Bruton, 1985).

The study on the effects of suspended solid on indigenous fish species has been done by Luciana (2003) but was carried out at 200 mg/l. This study was conducted at 300 mg/l of suspended solid. Therefore, the objectives of this study are to document the effects of suspended solid on mortality and growth of sayan *Leptobarbus hosii* and tengadak *Puntius schwanenfeldii* at a higher level of suspended solid.

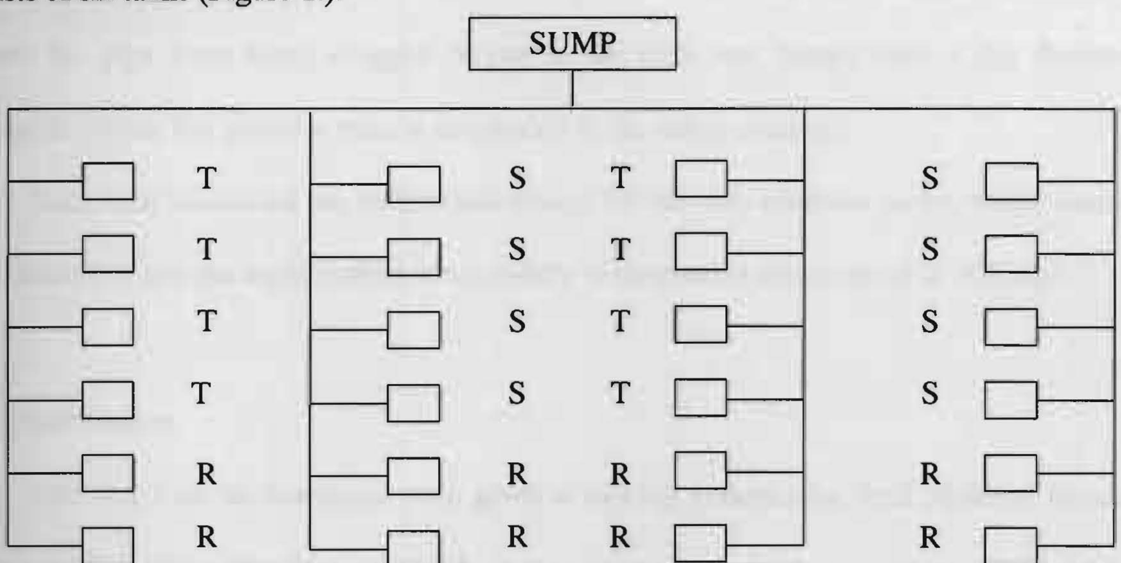
MATERIALS AND METHODS

Fish Fries

The fish fries of sayan and tengadak were obtained from the Inland Fisheries Branch of the Department of Agriculture in Tarat, Serian. The fish were acclimatized for one week to allow them to adapt to the new conditions and also to the commercial food. Fish samples for each species used in this study were of the same size with an average weight of 0.06 ± 0.03 gm for tengadak and 0.03 ± 0.01 gm for sayan.

Laboratory

This study was carried out at the Aquatic Vertebrate Laboratory, Faculty of Resource Science and Technology, UNIMAS. Two sets of recirculating culture system were used in this study. Each set has 24 glass tanks. The tanks were arranged in four rows, and each row consists of six tanks (Figure 1.).



T = Tengadak S = Sayan R = Reserved tank

Figure 1. The glass tanks plan that were used in this study.

Each tank on the clear water system have a dimension of 45 cm in length, 31 cm in height and 30 cm in width and a volume of 42 liters. Water level was kept at 23 cm in height, therefore the water volume was 32 liters. Each tank on the suspended solid system have a dimension of 44 cm in length, 31 cm in height and 29 cm in width and a volume of 40 liters. Water level was kept at 27 cm height, therefore the water volume was 34 liters.

Pump was used to provide a continuous water flow for each tank (JS Pump, Submersible Pump Multi Purpose) with a flow rate of 2 liters per minute (3.6 times complete water exchange every hour) for both systems. Domestic tap water that had been aerated for at least 3 days to get rid of the chlorine content was used in this study. Water that has been aerated was added to the sump to replace the water lost as a result of evaporation. The sump was covered with plastics to minimized evaporation.

Screens with a mesh size of 1 mm^2 were placed at the out flow pipe to sieve excrement while preventing the fish from entering the sump. These screens were cleaned everyday to prevent the pipe from being clogged. Water in the tank was stirred once a day (between feeding) to ensure the particles remain suspended in the water column.

Each tank contained ten individuals except for the two reserved tanks, which contain more. Both fish species were studied concurrently at suspended solids equal to 300 mg/l.

Feed Distribution

The fish fries in this study were given a sinking commercial feed obtained from an ornamental fish shop. The fries were fed seven percent of the body weight on the first week and six percent of the body weight for the following week. The amounts of food given were adjusted once every fortnight so that the food increments tally with the increments of the fish body weights (Simba, 2002). The fishes were fed twice a day at 0900 hours and 1600 hours.

The feed had to be crushed before given to the fishes. On week eight, the fish on suspended solid culture system was topped up because a lot of fishes died due to diseases.

Data Collections

Total length (TL), standard length (SL) and weight of five fish for each species in every tank was taken at the end of the two weeks study period. The fish body was first dip dried using tissues before being measured. The fish was then placed on a damped weighed petri dish. Then, the fish was weighed using an electronic scale. The reading was taken to the nearest 0.0001 gm. Total length and standard length was measured using a ruler taken to the nearest 0.1 cm.

Feed conversion ratio (FCR) was calculated following a protocol outlined by Tucker & Boyd (1998). Calculation for FCR is as follows:

$$FCR = \frac{\text{Dry weight of feed given}}{\text{Wet weight of harvested fish}}$$

Percentage of body weight increment (BWI %), total length increment (TLI %), and standard length increment (SLI %) was calculated using the formula below:

$$BWI\ (\%) = 100 \times (BW_f - BW_i) / BW_i$$

BW_f = Final body weight

BW_i = Initial body weight

$$TLI\ (\%) = 100 \times (TL_f - TL_i) / TL_i$$

TL_f = Final total length

TL_i = Initial total length

$SLI (\%) = 100 \times (SL_f - SL_i) / SL_i$

SL_f = Final standard length

SL_i = Initial standard length

Fish Mortality

Fishes were observed daily. The numbers of dead fishes were recorded. Subsequently, the dead fishes were immediately replaced by the same species of fish with almost the same size from the reserved tanks. Percentage of fish mortality would only take account of those fishes that were found dead in the tank while excluding the dead fishes resulting from the event of jumping out of the tank. Percent mortality was calculated as follows;

$$\text{Mortality} = (1 - \text{Survival}) \times 100$$

$$\text{Survival} = \frac{N_{(alive)}}{N_{(sample)}}$$

Water Quality

Water quality readings were measured once every two weeks. Parameters that were measured are pH, temperature, dissolved oxygen, nitrite, nitrate, ammonia nitrogen, BOD_5. Temperature and dissolved oxygen were measured by using the D.O meter (DO 300 Series). pH was measured using pH meter model 420 Orion. Nitrite, nitrate and ammonia nitrogen were measured by using the Hach Kit Model DR 2010. BOD_5 were measured using the standard methods by APHA (1998).

BOD_5 were calculated using the formula below:

$BOD_5 (mg/l) = (D_1 - D_5)/P$

D_1 = DO taken initially (mg/l)

D_5 = DO taken after 5 days (mg/l)

P = Volume of water sample used (L)

Particle Size Analysis

In this study soil was collected from a site near UNIMAS Chancellery. Soil sample were sieved using a sieve with a mesh size of 2 mm. The sieved sample was then weighed for 10 gram and put into a flask cone. 100 ml of distilled water was then added and was sealed using a parafilm. The flask was then left on the shaker for 18 hours at 6 rpm. Then the sample was sieved by using a sieve with a mesh size of 45 μm. The sieved sample was collected using a 1000 ml measuring cylinder. The sample on the sieve was rinsed with distilled water until the water that came out from the sieve was clear. Distilled water was then added until it reaches the 1000 ml level. Particles that were retained on the sieve were rinsed into a petri dish (sand fraction). For the fractions of coarse silt, fine silt and clay, the samples were put in water bath with temperature of 26 °C. The sample were stirred at 0 minute using a mechanical stirrer. The samples were pipetted by using a 25 ml pipet at a standard time scale (Table 1.) into a petri dish. All of the petri dishes were weighed before the sample fractions were put onto the dish. The petri dishes were then placed in the oven at a temperature of 105 °C and were left overnight. These fractions were weighed and the initial weights of the fractions were recorded. Particle sizes analysis were done in three replicates.

Table 1. Soil fractions analysis time scale for coarse silt, fine silt and clay.

Sample	Stir	Coarse silt (20μm)	Fine silt (5μm)	Clay (2μm)
Sample 1	0 min	4 min 1 sec	1h 4min 27sec	4h 30min
Sample 2	2 min	7 min 1 sec	1h 7min 27sec	4h 33min
Sample 3	4 min	13 min 1 sec	1h 13min 27sec	4h 39min

Particle sizes were calculated using the formula:

$$\text{Clay } (\%) = 100 \times (RW_2 \times CF) / TW$$

Where,

RW_2 = Residue weight (g) of 2μm fraction

CF = 1000 ml/DV

DV = Pipet volume

TW = Total weight of oven dry sample

$$\text{Fine Silt } (\%) = [100 \times (RW_{20} \times CF) / TW] - \text{Clay } (\%)$$

Where,

RW_{20} = Residue weight (g) of 20μm fraction

$$\text{Sand } (\%) = \text{Net weight} / TW \times 100$$

$$\text{Coarse silt } (\%)(20 \text{ to } 50\mu m) = 100 - (\text{Clay } (\%) + \text{Fine silt } (\%) + \text{Sand } (\%))$$

Suspended Solid in the Gills

Five fishes of about the same sizes from each species for both water systems were killed to determine the suspended solids accumulated in the gills. The fish gills were dissected. Each gill was then washed in a separate petri dish filled with distilled water. The initial weights of the filter paper were recorded. The sample was then filtered before it was left in the oven to be dried. The sample dry weight was then measured. The amounts of suspended solids were determined using the standard method of APHA (1998).

Statistical Analysis

Calculation and descriptive statistics were carried out using the SPSS 11.0. One way analysis of variance (ANOVA) was used to determine the overall significant differences between fish species and between suspended solid and clear water for total length, standard length, weight and FCR. Multiple comparisons were perform using Fisher's Protected Least Significant Difference (LSD) to pin point the one or more means that contribute to the rejection of the overall *Ho.* Finally a power regression was used to test correlation between total length with standard length, total length with body weight and standard length with body weight for both fish species in suspended solid culture system and clear water culture system.

RESULT

General Observation

At the beginning of the experiment, the fishes were found to be under stress due to the new conditions. They were observed to be sensitive of human present such as swimming to the opposite direction of people nearby and only ate when no one was near their tank. It was only fishes in the research system that seems to take a longer time to adapt to the new environment. After three weeks, the fishes were more relax and fonder. Tengadak seems to be more active than sayan, they tend to jump off the tank more often. Tengadak swim at the middle to bottom level of tank and ate sinking feed. While, sayan swim at the upper lever of tank and ate floating feed. At the end of the experiment, both fish species in the research system have a darker colour than the control system. This may be due to the turbid water in the research system.

Fish Mortality

In suspended solid culture system, mortality rate for sayan was higher than tengadak. At the end of the experiment, mortality rate for sayan was 30 % and for tengadak was 21.25 % (Figure 2).

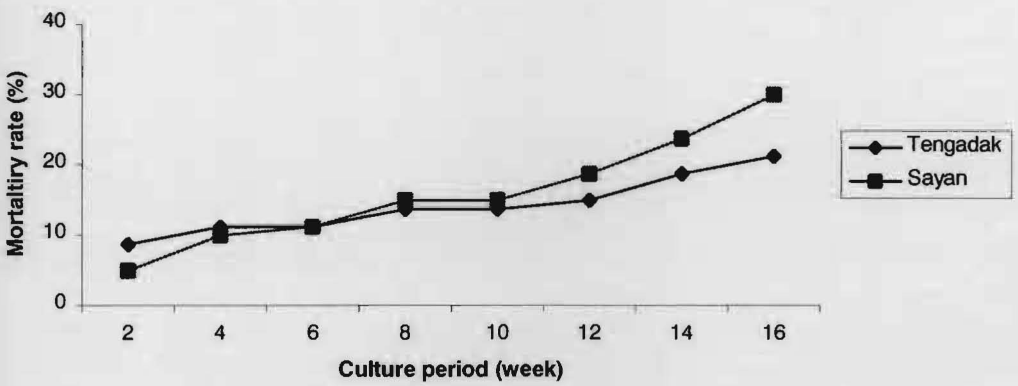


Figure 2. Percentage of mortality of tengadak and sayan in suspended solid.

In clear water culture system, mortality rate for tengadak was higher than sayan. At the end of the experiment, mortality rate for tengadak was 40 % and for sayan was 2.5 % (Figure 3).

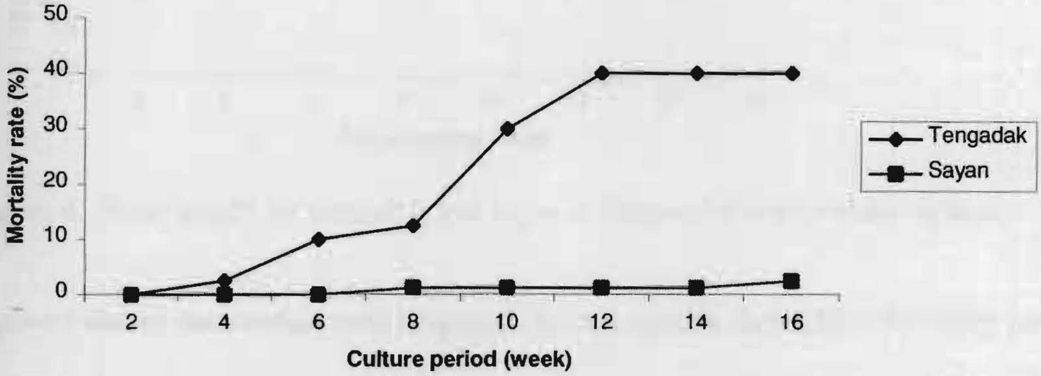


Figure 3. Percentage of mortality of tengadak and sayan in clear water.

Growth Rate

Total Length

Figure 4 shows the average total length of the two species throughout the study period in suspended solid culture system. At the end of the study period, sayan had the highest total length (4.70 ± 0.47 cm) followed by tengadak (4.3 ± 0.52 cm). Significant differences in total length of tengadak were detected during week 10 to week 16 ($P \le 0.029$). Total length of sayan increased significantly on week 10 to week 16 ($P \le 0.002$).

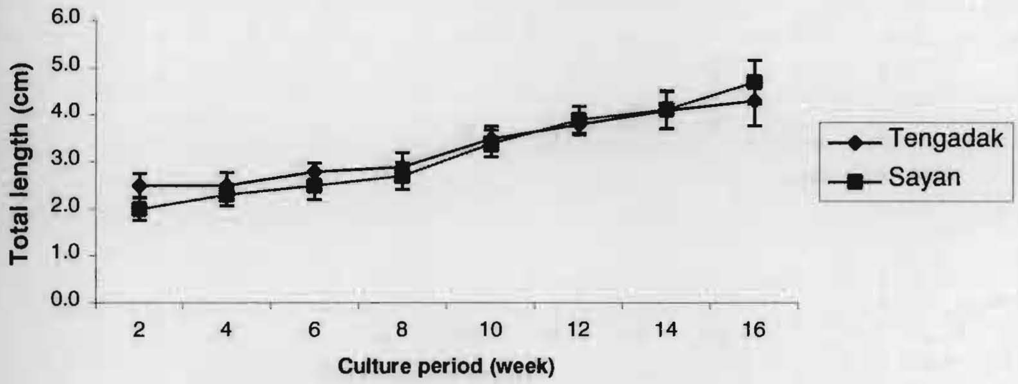


Figure 4. Total length for tengadak and sayan in suspended solid culture system.

Figure 5 shows the average total length of the two species throughout the study period in clear water culture system. At the end of the study period, sayan had the highest total length (4.40 ± 0.473 cm) followed by tengadak (4.2 ± 0.289 cm). Total length of sayan increased significantly on week 10 to week 16 ($P \leq 0.001$). Total length of tengadak increased significantly on week 10, week14 and week 16 ($P \leq 0.003$).

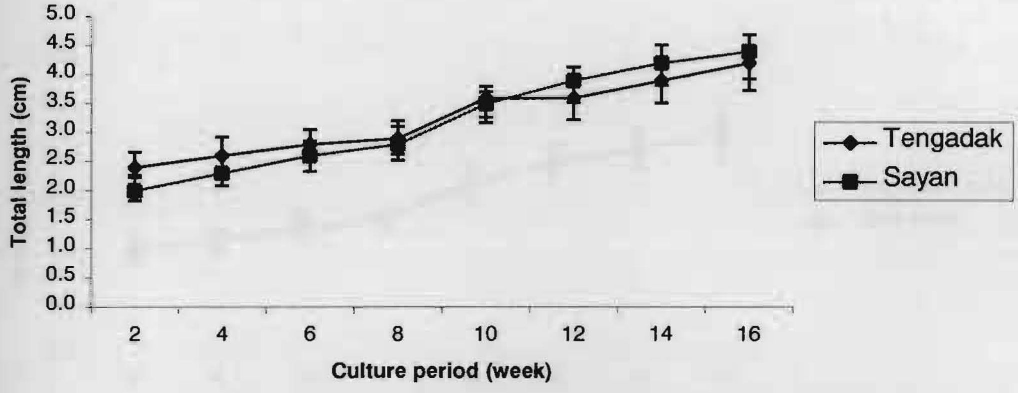


Figure 5. Total length for tengadak and sayan in clear water culture systems.

Figure 6 shows the average total length of the tengadak throughout the study period in suspended solid and clear water culture system. There was no significant difference in total length for tengadak between suspended solid (4.30 ± 0.52 cm) and clear water system (4.20 ± 0.29 cm) during study period ($P \leq 0.950$).

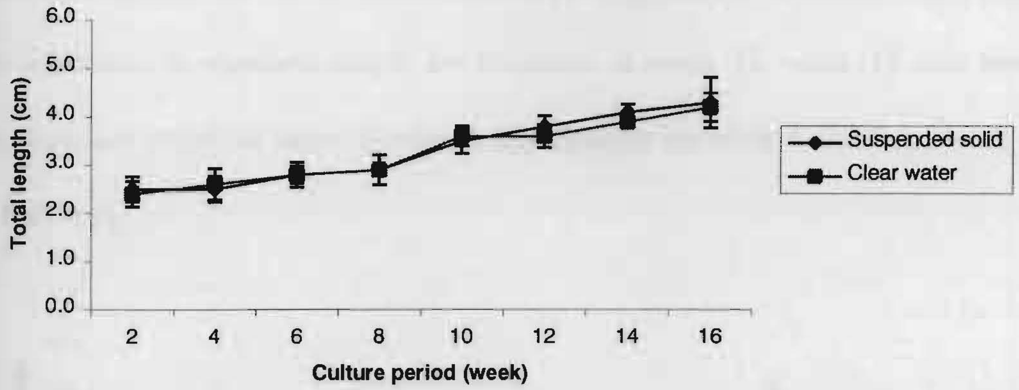


Figure 6. Total length for tengadak in suspended solid and clear water culture systems.

Figure 7 shows the average total length of the sayan throughout the study period in suspended solid and clear water culture. At the end of the study period, suspended solid had the highest total length followed by clear water. There was significant difference in total length for sayan between suspended solid (4.70 ± 0.47 cm) and clear water system (4.40 ± 0.47 cm) detected at week 16 ($P \leq 0.046$).

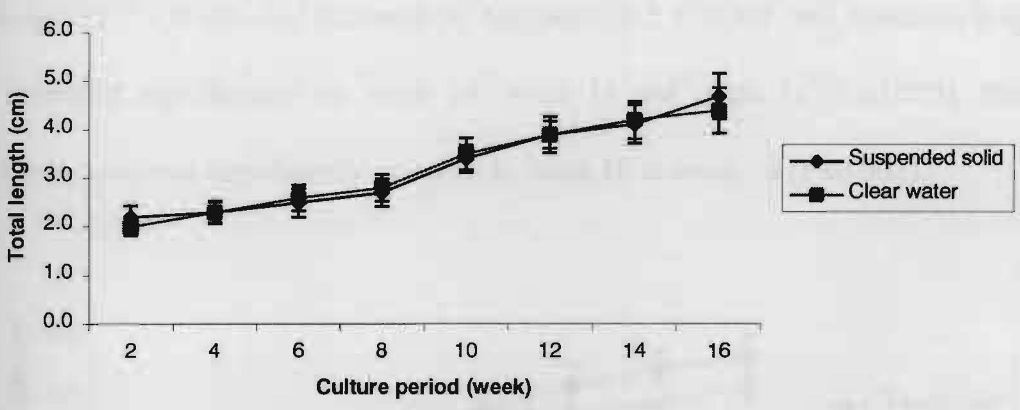


Figure 7. Total length for sayan in suspended solid and clear water culture systems.

Standard Length

Figure 8 shows the average standard length of the two species throughout the study period in suspended solid culture system. At the end of the study period, sayan had the highest standard length (3.90 ± 0.467 cm) followed by tengadak (3.4 ± 0.346 cm). There was significant difference in standard length for tengadak at week 10, week 14 and week 16 (P≤0.035). Standard length of sayan increased significantly on week 4 and from week 10 to week 16 (P≤0.041).

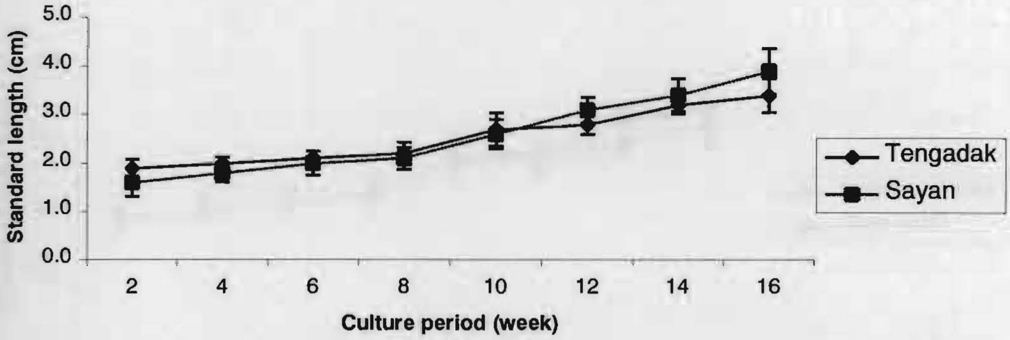


Figure 8. Standard length for tengadak and sayan in suspended solid culture system.

Figure 9 shows the average standard length of the two species throughout the study period in clear water culture system. At the end of the study period, sayan had the highest standard length (3.7 ± 0.386 cm) followed by tengadak (3.2 ± 0.289 cm). Standard length of tengadak increased significantly on week 10, week 14 and week 16 (P≤0.020). Standard length of sayan increased significantly on week 6, week 10 to week 14 (P≤0.002).

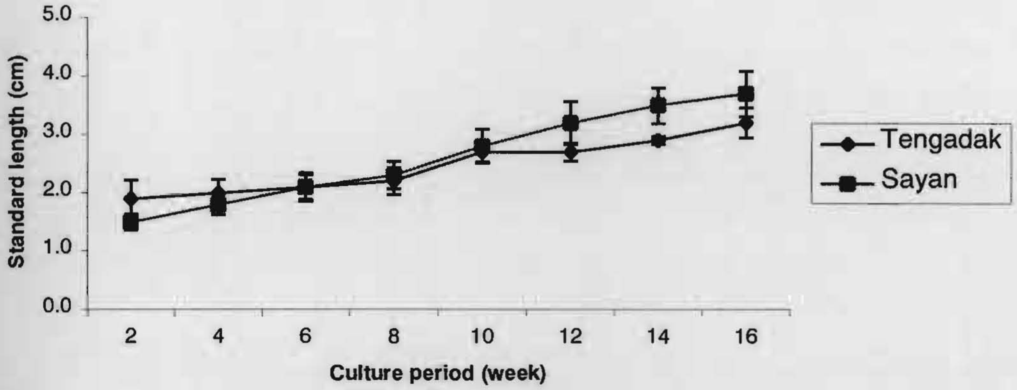


Figure 9. Standard length for tengadak and sayan in clear water culture system.

Figure 10 shows the average standard length of the tengadak throughout the study period in suspended solid and clear water culture. At the end of the study period, suspended solid had the highest standard length (3.40 ± 0.346 cm) followed by clear water (3.2 ± 0.254 cm). There was significant difference in standard length for tengadak between suspended solid and clear water system at week 14 (P≤0.028).

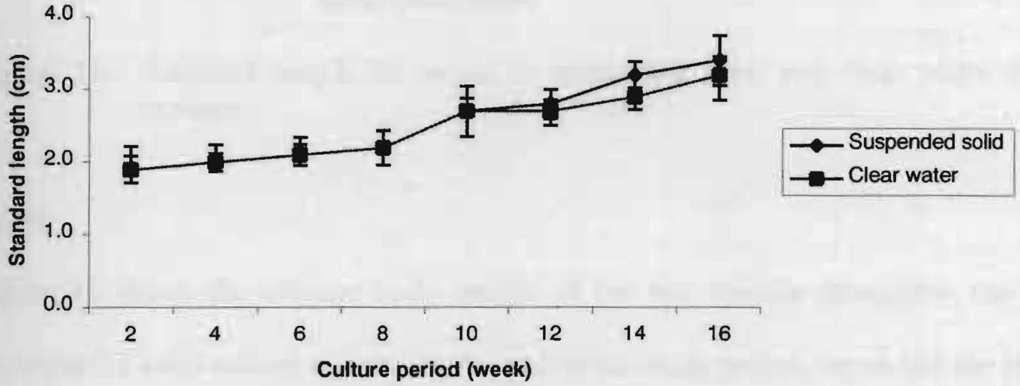


Figure 10. Standard length for tengadak in suspended solid and clear water culture systems.

Figure 11 shows the average standard length of the sayan throughout the study period in suspended solid and clear water culture. There was no significant difference in standard length for sayan between suspended solid (3.90 ± 0.476 cm) and clear water system (3.7 ± 0.386 cm) during study period (P≤0.835)

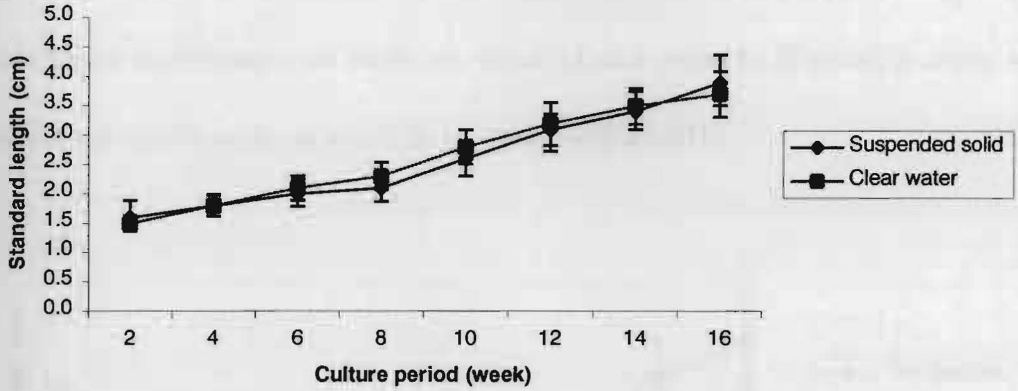


Figure 11. Standard length for sayan in suspended solid and clear water culture systems.

Body Weight

Figure 12 shows the average body weight of the two species throughout the study period in suspended solid culture system. At the end of the study period, sayan had the highest body weight (1.5630 ± 0.496 gm) followed by tengadak (1.1626 ± 0.351 cm). Body weight of tengadak increased significantly on week 10 to week 16 (P≤0.029). Body weight of sayan increased significantly on week 10 to week 16 (P≤0.002).

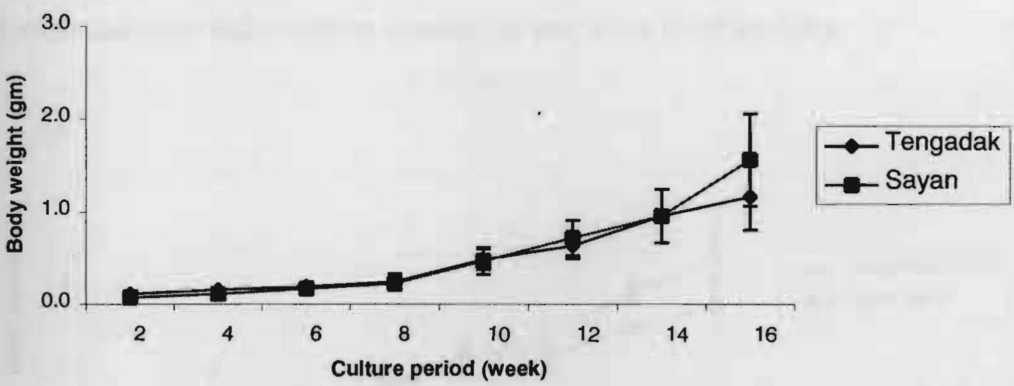


Figure 12. Body weight for tengadak and sayan in suspended solid culture system.

Figure 13 shows the average body weight of the two species throughout the study period in clear water culture system. At the end of the study period, sayan had the highest body weight (1.3306 ± 0.369 gm) followed by tengadak (0.8672 ± 0.187 cm). Body weight of tengadak increased significantly on week 10, week 14 and week 16 (P≤0.002). Body weight of sayan increased significantly on week 10 to week 16 (P≤0.003).

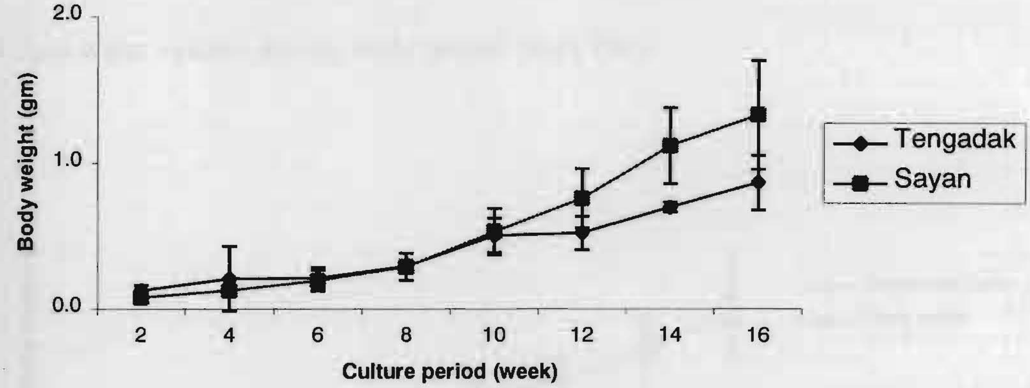


Figure 13. Body weight for tengadak and sayan in clear water solid culture system.

Figure 14 shows the average body weight of tengadak throughout the study period in suspended solid and clear water culture. At the end of the study period, the fish cultured in suspended solid had the highest body weight (1.1626 ± 0.351 gm) followed by clear water (0.8672 ± 0.187 gm). There was significant difference in body weight for tengadak between suspended solid and clear water system at week 14 and week 16 (P≤0.021).

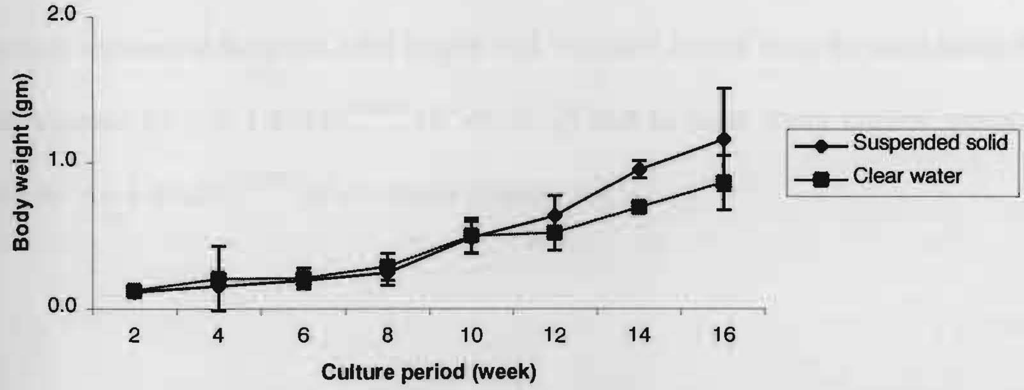


Figure 14. Body weight for tengadak in suspended solid and clear water culture systems.

Figure 15 shows the average body weight of sayan throughout the study period in suspended solid and clear water culture system. At the end of the study period, suspended solid had the highest body weight (1.5630 ± 0.496 gm) followed by clear water (1.3306 ± 0.369 gm). There was no significant difference in body weight for sayan between suspended solid and clear water system during study period ($P \leq 0.740$).

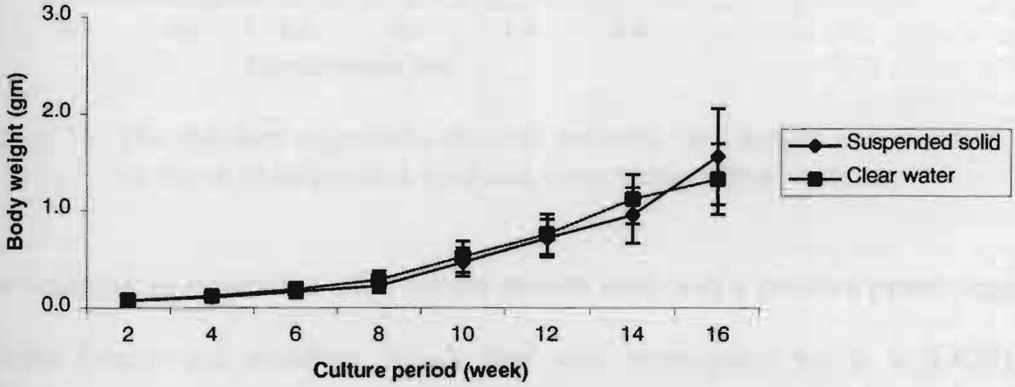


Figure 15. Body weight for sayan in suspended solid and clear water culture systems.

Regression

Power regression plot were constructed by comparing total length with standard length, total length with body weight, and standard length with body weight for sayan and tengadak in suspended solid culture system and clear water culture system. Sayan showed a positive power regression between total length and standard length in suspended solid culture system represented by $y = 1.3814x^{0.9009}$ (R^2=0.9572) and in clear water culture system was represented by $y = 1.3929x^{0.8852}$ (R^2=0.9868) (Figure 16).

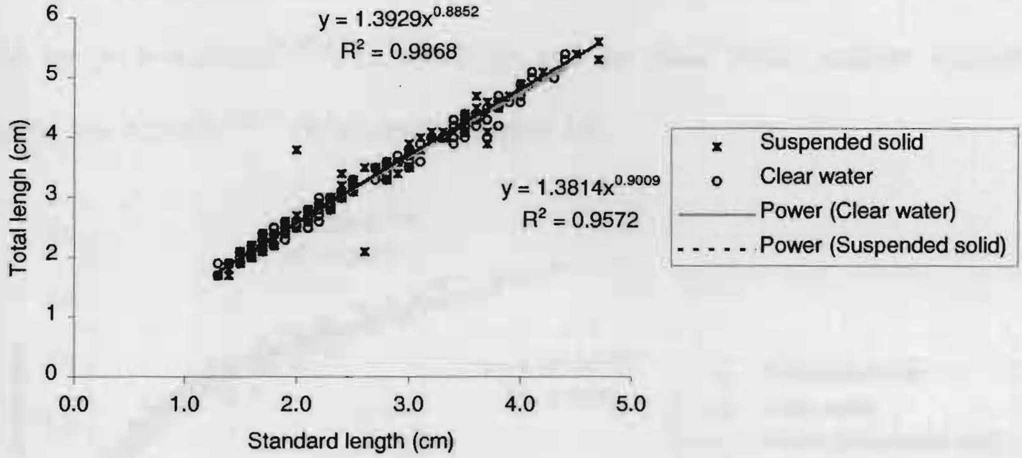


Figure 16. The standard regression analysis between total length and standard length for sayan in suspended solid and clear water culture systems.

For tengadak in suspended solid culture system there was a positive power regression between total length and standard length that was represented by $y = 1.4291x^{0.8968}$ (R^2=0.8825) and in clear water culture system was represented by $y = 1.3545x^{0.9659}$ (R^2=0.9344) (Figure 17).

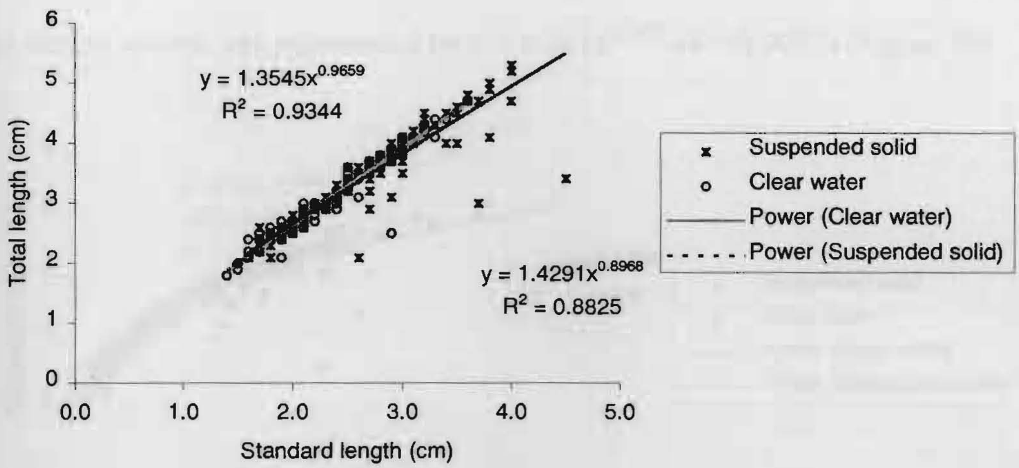


Figure 17. The standard regression analysis between total length and standard length for tengadak in suspended solid and clear water culture systems.

For sayan in suspended solid, the regression between total length and body weight was represented by $y = 4.2024x^{0.2812}$ (R^2=0.9812) and in clear water culture system was represented by $y = 4.1217x^{0.2755}$ (R^2=0.9637) (Figure 18).

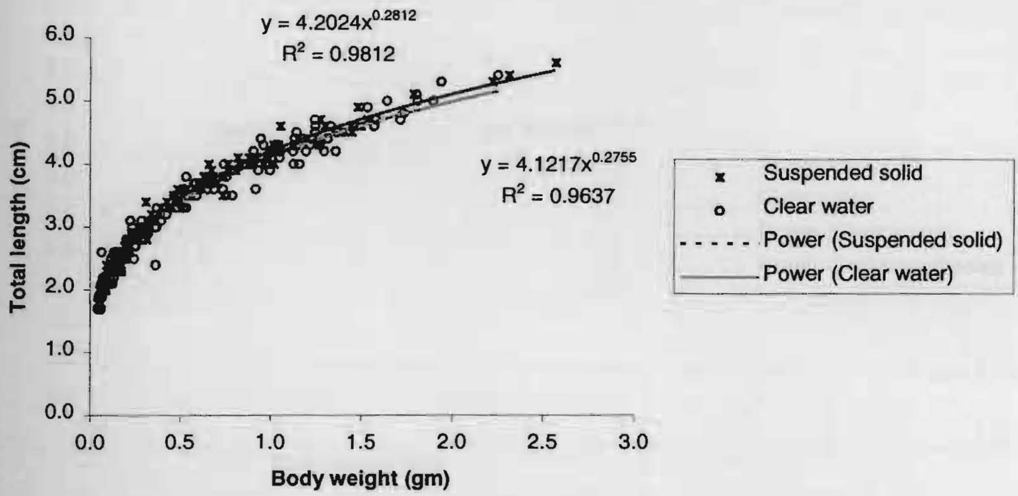


Figure 18. The standard regression analysis between total length and body weight for sayan in suspended solid and clear water culture systems.

There is a positive power regression for tengadak in suspended solid culture system between total length and body weight represented by $y = 4.1965x^{0.2565}$ (R^2=0.9412) and in clear water culture system was represented by $y = 4.241x^{0.2658}$ (R^2=0.9073) (Figure 19)

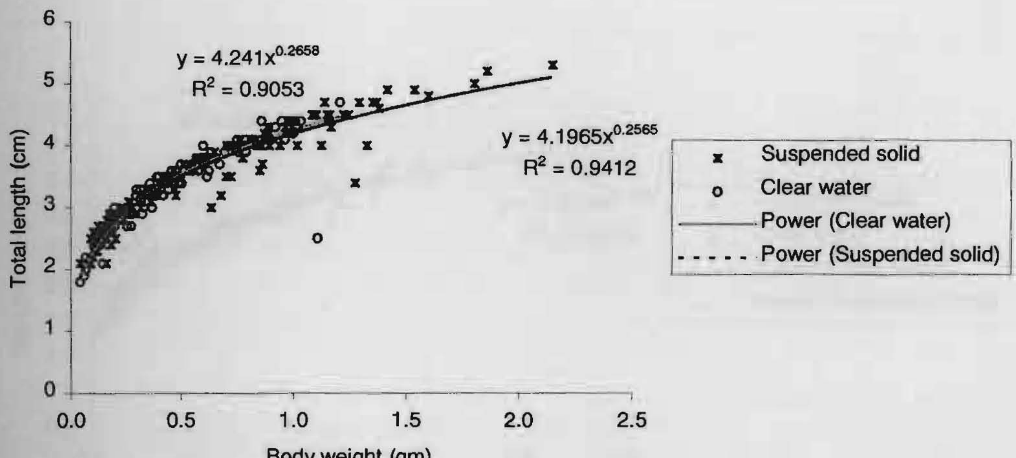


Figure 19. The standard regression analysis between total length and body weight for tengadak in suspended solid and clear water culture systems.

For sayan in suspended solid the regression between standard length and body weight had positive regression that was represented by $y = 3.3903x^{0.3012}$ ($R^2=0.9545$) and in clear water culture system was represented by $y = 3.4027x^{0.3102}$ ($R^2=0.9705$) (Figure 20).

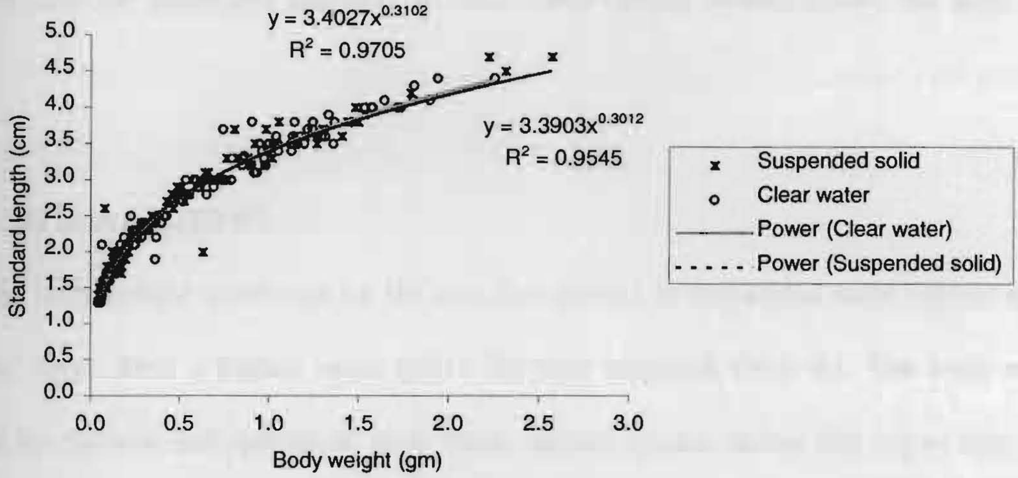


Figure 20. The standard regression analysis between standard length and body weight for sayan in suspended solid and clear water culture systems.

For tengadak in suspended solid culture system, the regression relation between standard length and body weight was represented by $y = 3.2578x^{0.2664}$ ($R^2=0.9254$) and in clear water culture system the regression was represented by $y = 3.2037x^{0.2608}$ ($R^2=0.8702$) (Figure 21).

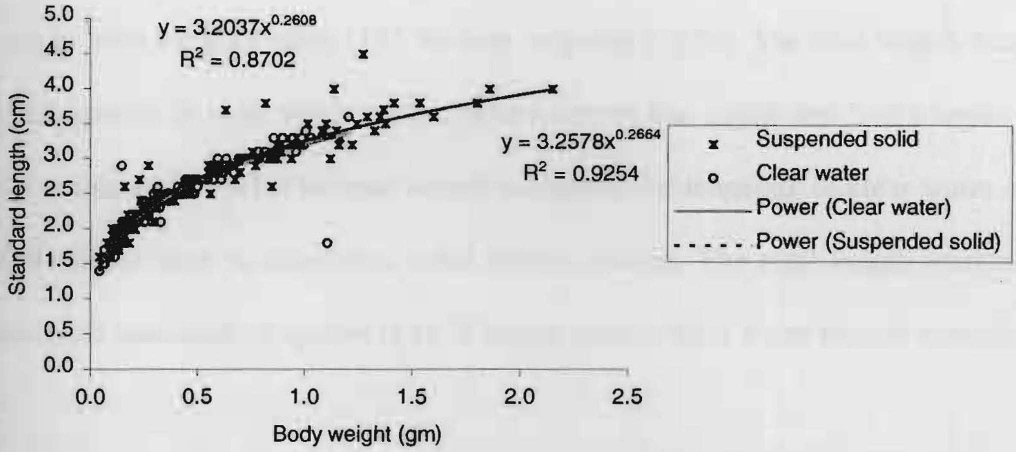


Figure 21. The standard regression analysis between standard length and body weight for tengadak in suspended solid and clear water culture systems.

Feed Conversion Ratio (FCR)

The feed conversion ratio for the two fish species in suspended solid culture system shows that sayan gives a slightly higher value (0.300) than tengadak (0.299). The feed conversion ratio for sayan and tengadak in clear water culture system shows the same value (0.299).

Body Weight Increment (BWI)

The body weight increment for the two fish species in suspended solid culture system shows that sayan have a higher value (5551 %) than tengadak (964 %). The body weight increment for the two fish species in clear water culture system shows that sayan also had a higher value (4711 %) than tengadak (694 %). The body weight increment for tengadak in suspended solid culture system is 28 % higher than in clear water culture system. The body weight increment of sayan in suspended solid culture system is 15 % higher than in clear water culture system.

Total Length Increment (TLI)

The total length increment for the two fish species in suspended solid culture system shows that sayan have a higher value (137 %) than tengadak (72 %). The total length increment for the two fish species in clear water culture system shows that sayan also had a higher value (121 %) than tengadak (75 %). The total length increment for tengadak in clear water culture system is 4 % higher than in suspended solid culture system. The total length increment of sayan in suspended solid culture system is 11 % higher than in clear water culture system.

Standard Length Increment

The standard length increment for the two fish species in suspended solid culture system shows that sayan have a higher value (144 %) than tengadak (79 %). The standard length increment for the two fish species in clear water culture system shows that sayan also had a higher value (145 %) than tengadak (68 %). The standard length increment for tengadak in suspended solid culture system is 13 % higher than in clear water culture system. The standard length increment of sayan in suspended solid culture system is 0.66 % higher than in clear water culture system.

Suspended Solid in Gills

The amounts of suspended solids in the gills were higher for both species cultured in the suspended solid culture system. On the other hand, the amount of suspended solid in the gill of sayan was higher than the amount in tengadak for both clear water and turbid water systems. In suspended solid system, the average value of suspended solids in gills for sayan and tengadak was 0.00074 ± 0.00037 gm and 0.00063 ± 0.00021 gm respectively. While, in clear water system the average value of suspended solid in gills for sayan and tengadak was 0.00054 ± 0.00029 gm and 0.00045 ± 0.00022 gm respectively.

Particle Size Analysis

The soil used in this experiment consisted of 10.44 ± 0.49 % clay, 26.23 ± 2.91 % fine silt, 28.18 ± 2.56 % coarse silt and 35.16 ± 0.54 % sand. Based on the USDA classification scheme, the soil used in this study was loam (Gee and Bauder, 1986). The soil fraction compositions are shown in Table 2.

Table 2. Soil fractions composition.

Soil fraction	Percentage (Average ± SD)
Clay	10.44 ± 0.49
Fine silt	26.23 ± 2.91
Coarse silt	28.18 ± 2.56
Sand	35.16 ± 0.54

Water Quality

Temperature

Figure 22 shows the average reading for water temperature in the suspended solid and clear water culture systems throughout the study period. Temperature in the suspended solid culture system was between 23.3 °C and 28.6 °C. While, the temperature in the clear water culture system was between 24.0 °C and 28.0 °C. There were significant difference in temperature between the suspended solid culture systems and clear water on week 4 to week 16 ($P \leq 0.000$).

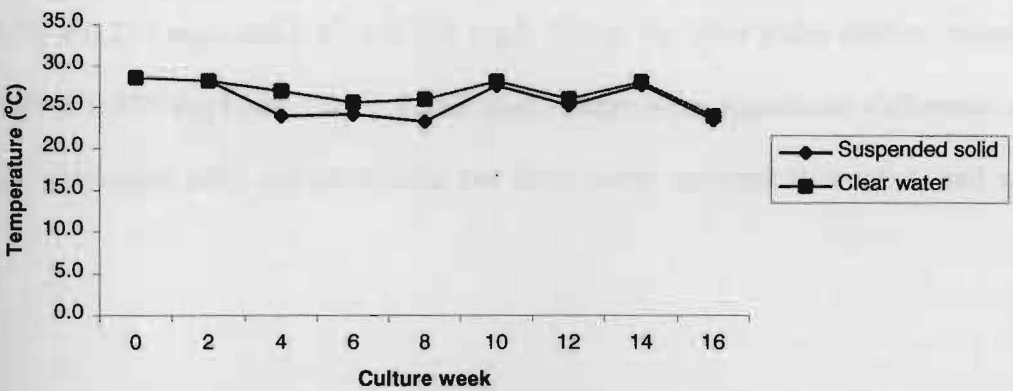


Figure 22. Average temperature for suspended solid and clear water culture systems.

pH

Figure 23 shows the average reading for pH in the suspended solid and clear water culture systems throughout the study period. pH in the suspended solid culture system was between 6.97 ± 0.12 and 7.82 ± 0.02. pH in the clear water culture system was between 7.46 ± 0.02 and 7.83 ± 0.04. There were significant difference in pH between the suspended solid culture systems and clear water on week 0, week 6 to week 12 and on week 16 ($P \leq 0.039$).

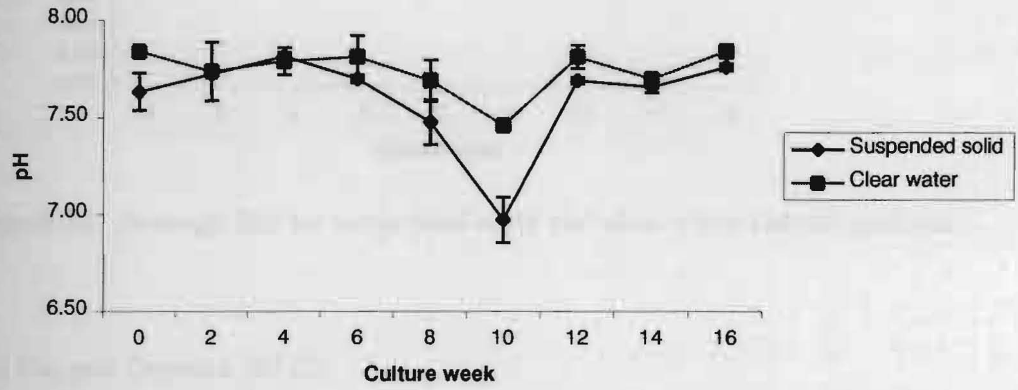


Figure 23. Average pH for suspended solid and clear water culture systems.

Dissolved Oxygen (DO)

Figure 24 shows the average reading for DO in the suspended solid and clear water culture system throughout the study period. DO in the suspended solid culture system was between 6.78 ± 0.217 mg/l and 8.87 ± 0.219 mg/l. DO in the clear water culture system was between 6.89 ± 0.557 mg/l and 9.03 ± 0.080 mg/l. There were significant difference in DO between the suspended solid culture system and clear water on week 0, week 4, and week 8 ($P \leq 0.1$).

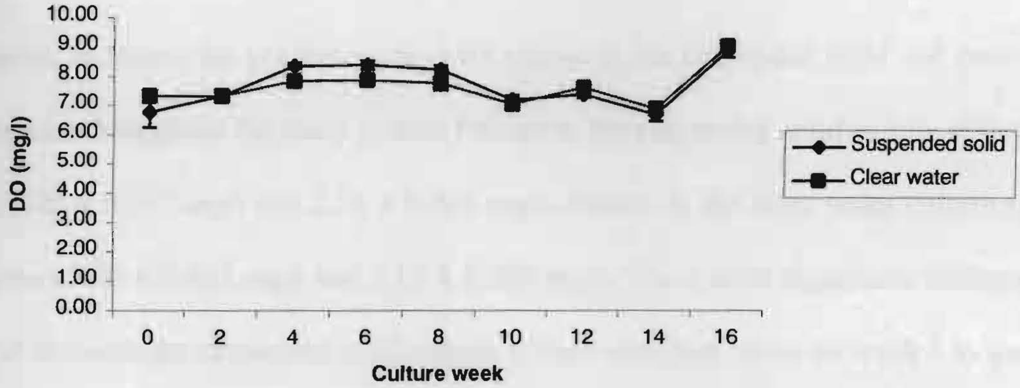


Figure 24. Average DO for suspended solid and clear water culture systems.

Biological Oxygen Demand (BOD)

Figure 25 shows the average reading for BOD in the suspended solid and clear water culture systems throughout the study period. BOD in the suspended solid culture system was between 1.97 ± 1.131 mg/l and 9.06 ± 0.764 mg/l. BOD in the clear water culture system was between 2.45 ± 0.635 mg/l and 7.37 ± 0.717 mg/l. There were significant difference in BOD between the suspended solid culture system and clear water on week 0 to week 10 and on week 14 to 16 ($P \leq 0.008$).

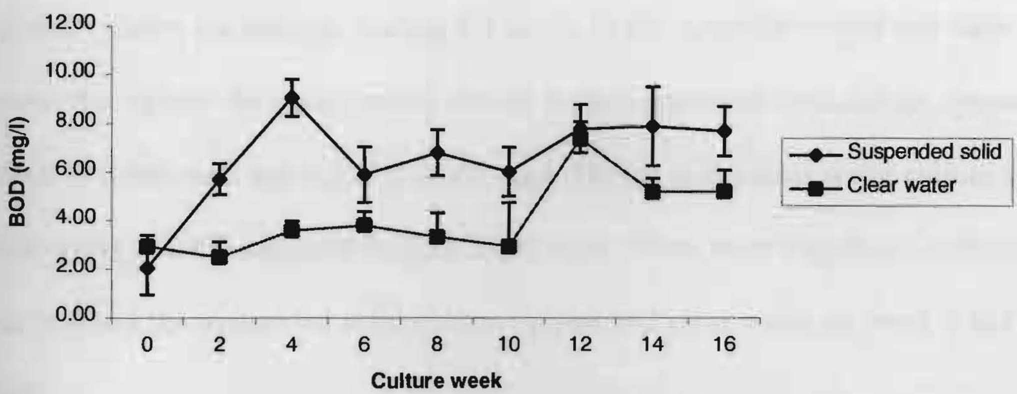


Figure 25. Average BOD for suspended solid and clear water culture systems.

Nitrate

Figure 26 shows the average reading for nitrate in the suspended solid and clear water culture systems throughout the study period. Nitrate in the suspended solid culture system was between 0.226 ± 0.352 mg/l and 2.58 ± 0.321 mg/l. Nitrate in the clear water culture system was between 0.820 ± 0.453 mg/l and 3.12 ± 0.258 mg/l. There were significant difference in nitrate level between the suspended solid culture system and clear water on week 4 to week 12 ($P \leq 0.001$).

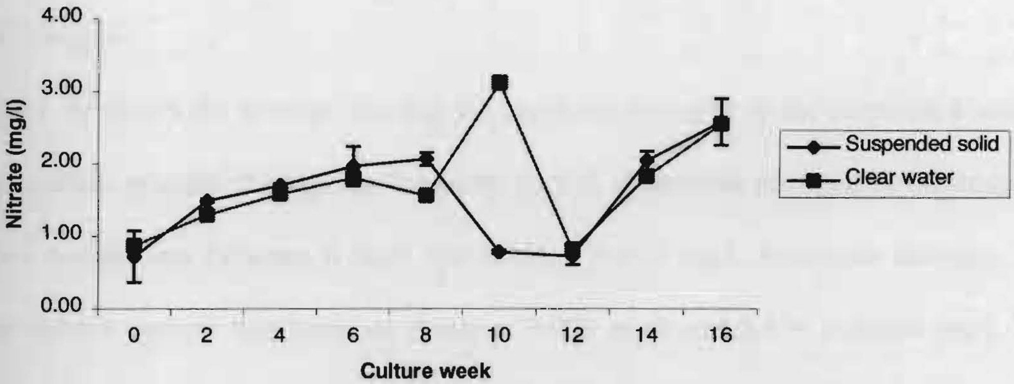


Figure 26. Average nitrate for suspended solid and clear water culture systems.

Nitrite

Figure 27 shows the average reading for nitrite in the suspended solid and clear water culture system throughout the study period. Nitrite in the suspended solid culture system was between 0.003 ± 0.000 mg/l and 0.127 ± 0.001 mg/l. Nitrite in the clear water culture system was between 0.004 ± 0.000 mg/l and 0.132 ± 0.007 mg/l. There were significant difference in nitrite level between the suspended solid culture system and clear water on week 8 and week 10 ($P \leq 0.002$).

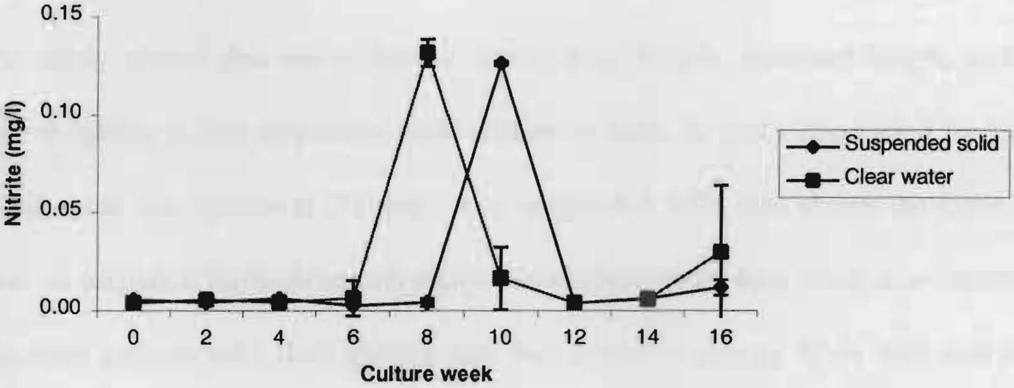


Figure 27. Average nitrite for suspended solid and clear water culture system.

Ammonia Nitrogen

Figure 28 shows the average reading for ammonia nitrogen in the suspended solid and clear water culture systems throughout the study period. Ammonia nitrogen in the suspended solid culture system was between 0 mg/l and 0.156 ± 0.017 mg/l. Ammonia nitrogen in the clear water culture system was between 0.000 ± 0.000 mg/l and 0.138 ± 0.029 mg/l. There were significant difference between the suspended solid and clear water culture system on week 8 ($P \leq 0.023$).

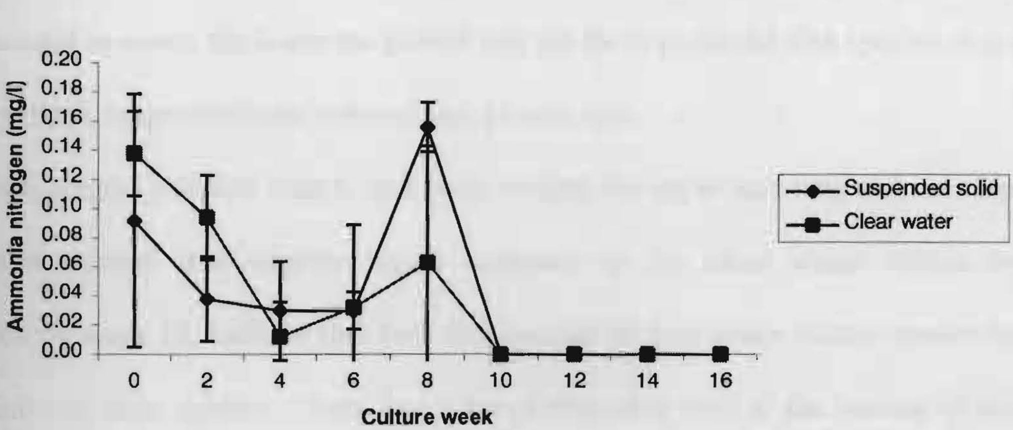


Figure 28. Average ammonia nitrogen for suspended solid and clear water culture systems.

DISCUSSION

This study shows that sayan have a higher total length, standard length, and body weight than tengadak in the suspended solid culture system. A study conducted by Luciana (2003) on the same fish species at 200 mg/l total suspended solid also shows the same result. Observation on tengadak throughout this study period shows that they were more active than sayan. This may explain why their growth rate was lower as energy from feed was mostly used for swimming and other life function such as respiration and digestion rather than for growth (Lokman, 1990).

Body weight, total length, and standard length for sayan and tengadak in 200 mg/l suspended solid conducted by Luciana (2003) are higher than in 300 mg/l suspended solid as in this study. As for comparison to previous study by Luciana (2003), it is interesting to note that there are decrement of body weight exposed to 300 mg/l for sayan and tengadak are 35.5 % and 46.5 % respectively. Percentage decrease in total length for sayan and tengadak are 71.9 % and 78.9 % respectively and standard length percentage decrease for sayan and tengadak are 72.0 % and 82.3 % respectively. This shows that the higher the concentration of suspended solid in water, the lower the growth rate for these particular fish species. According to Bruton (1985), suspended solid reduced fish growth rate.

Total length, standard length, and body weight for sayan and tengadak in suspended solid culture system was slightly higher compare to the clear water culture system. Observation on week 12, indicate that both fish species in clear water culture system became inactive and lost their appetite. There was a lot of excessive feed at the bottom of the tank. Tengadak has more excess feed than sayan. Which, shows that tengadak is more sensitive than sayan. The death of the fishes may due to the infection of disease that was caused by the presence of the white organism at the surface of the tanks and at the aeration tube. After the clear water culture system was cleaned, the growth for both species increased but was still lower than in suspended solid. This might be because they needed time to recover. A study conducted by Ardjosoediro and Ramnarine (2002) shows that there were significant decreases in weight gain and length as turbidity increased.

In suspended solid culture system, body weight, total length, and standard length for sayan were slightly higher than tengadak. This shows that sayan was well adapted to turbid water than tengadak. Inger and Chin (1962) reported the presence of sayan in turbid water of large rivers.

Growth rate of both species in this study can be affected by the handling techniques practiced by the researcher that lead to the physiological effects on fish (Miles *et al.* 1974; Mazeaud *et al.*, 1977; Adedire and Oduleye, 1983; Matty, 1985; Kutty, 1986). Observation from this study shows that the fish's scales fall off from their body each time sampling is being carried out. This injury could slow the growth rate of the fish.

According to Luciana (2003) and Dianna (2003), mortality rate of sayan and tengadak in suspended solid culture system was higher than in clear water system. However, in this study mortality rate for sayan and tengadak was higher in clear water culture system than suspended solid culture system. This is cause by the disease infection in clear water culture system. Even though sayan have a high growth rate in suspended solid culture system, but it has a higher mortality rate than tengadak.

Sayan has a higher amount of solids attached to their gills than tengadak. The higher concentration of solid accumulated in their gills could be due to an opened structure of their operculum. This shows that suspended solid does not seem to affect sayan's growth rate, but the high accumulation of suspended solid in gills caused a higher mortality than tengadak (Luciana, 2003). Suspended solid attached to gills can cause gills irritation (Bruton, 1985).

Irritation of the gill membranes could lead to increase mucus production causing reduction in oxygen diffusion and resulted in fish respiratory distress (Jobling, 1995). The mechanical action of suspended solid can lead to clogging and irritation of gills (Stickney, 1979; Bruton, 1985) and generally suffocate fish (Sulaiman, 1994).

Recirculating culture system was used in this study. Therefore, there are no significant differences of water quality between the fish tanks. Suspended solid culture system has a temperature within the range of 23.3 to 28 °C and as for clear water culture system between 23 to 28 °C. According to Leh (1998), the temperature in natural habitat for both fish species is between 24.0 °C and 26.5 °C. The pH reading during this study period was between the range 6.97 and 7.82 for suspended solid culture system and 7.46 to 7.83 for clear water culture system. The pH in the natural habitat for both fish species is 6.8 to 7.5 (Leh, 1998).

Dissolved oxygen (DO) is critical for the survival of aquatic organisms (Landman and Heuvel, 2003). Dissolved oxygen readings in suspended solid culture system were 6.78 mg/l to 8.87 mg/l and in clear water culture system were 6.87 mg/l to 9.03mg/l. Brungs (1971) said that fish fries growth rates decreased when dissolved oxygen was lower than 7.8 mg/l. The low dissolved oxygen could be one of the factors affecting the fish growth during this study period. Biological oxygen demand in suspended solid culture system is higher (9.06 mg/l) than in clear water culture system (7.37 mg/l). This shows that there are other organism presences in turbid water that competes with the fish to take up oxygen. According to Bruton (1985), particulate matters suspended in water provide surfaces of attachment for bacteria.

The high amount of nitrate, nitrite, and ammonia nitrogen in the systems could be due to the excessive feed given. However, the lower amount of nitrate in suspended solid culture system could be due to the consumption by other organisms growing on the suspended solid such as fungi (Brunton, 1985).

CONCLUSION

This study shows that the effect of suspended solid differs among different species even thought they are of the same life stage. However, even similar trend are shown, whereby, an increase in suspended solid would result in decrease growth rate and increase mortality rate. This indicates that habitat with high concentration of suspended solid in water is less productive for sayan and tengadak.

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